IMO Train the Trainer (TTT) Course

on

Energy Efficient Ship Operation

The Course Exercises

Overview

The exercises provided in this document is developed for use within the TTT course on "Energy Efficient Ship Operation"; or subsequently by those who have undergone the full TTT course training as "Trainers" and intend to deliver the same course or a related customized course in their own country or region.

It provides a resource for trainers and instructors but does not limit them in any way to develop their own exercises or coursework. The intention is to support the Trainer during his/her training as well as with his/her follow-on delivery of similar trainings.

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Module 1 Exercises

Exercise 1.1 – Shipping air emissions and their impacts

Discuss the following aspects:

- Types of air emissions from ships and the main source of their generation.
- Impact of air emissions from ships?
- CO_2 emissions produced by human being: Where do they go or end up?
- Is there any cost associated with air emissions? Name.

Exercise 1.2 – Global response to climate change control

Use post-it notes; write the global/international activities and requirements with regard to control of GHG emissions and the mitigation of climate change.

In your response, please also refer to organisations/conventions/protocols/etc. that has been established as a result.

Exercise 1.3 – International shipping response to climate change control

Use post-it notes; write the IMO activities and requirements with regard to control of GHG emissions from international shipping.

Please refer to main activities (such as studies, debates) and requirements (such as regulations) in your deliberations.

Exercise 1.4 – Role and responsibilities at global levels

Explain the role of the following in relation to climate change control:

- IPCC [Intergovernmental Panel on Climate Change]
- UNFCCC [United Nation Framework Convention for Climate Change]
- Kyoto Protocol
- Annex I countries
- IMO

Module 2 Exercises

Exercise 2.1 – Main abbreviations/acronyms in ship energy efficiency

Expand the following acronyms:

Acronym	Expanded
EEDI	
SEEMP	
EEOI	
MEPC	
MRV	
IEEC	
EETs	
EEMs	
MACC	

Exercise 2.2 – Regulatory requirements

Insert TRUE or FALSE at the end of each statement:

Statement	True or False?
EEDI is applicable to both new and existing ships.	
For any specific ship type and ship size, the Attained EEDI is independent of "EEDI implementation phases" but the Required EEDI changes from one phase to the next.	
We can have a common or same SEEMP document for all ships in the fleet.	
It is a requirement to have the contents of the SEEMP approved.	
Establishing/calculating the EEOI is voluntary.	
Chapter 3 of MARPOL Annex VI deals with regulations on energy efficiency for ship	
A "Record of Construction Relating to Energy Efficiency" is needed to be issued for issue of International Energy Efficiency certificate.	
Required EEDI means the actual EEDI of a ship as calculated according to relevant IMO Guidelines	

Exercise 2.3 – Test on EEDI Calculation Guidelines

(a) Review the table below:

TERM		DEFINITION	
A	Attained EEDI	**K**	The ship deadweight or gross tonnage at summer load line (for container ships, 70% of deadweight applies).
B	New ship (for EEDI)	**L**	Main engine power at NCR
C	Reference Line	**M**	A verification that takes place at the ship's design phase.
D	Reference Speed	**N**	The regulatory curve indicating NO_x limit as a function of engine speed.
E	Required EEDI	**O**	The development of EEDI Technical File.
F	Capacity (in EEDI formula)	**P**	A ship for which the building contract is placed on or after 1 January 2013 OR in the absence of a building contract, the keel of which is laid or which is at a similar stage of construction on or after 1 July 2013; OR the delivery of which is on or after 1 July 2015.
G	EEDI waiver	**Q**	Ship design speed
H	P_{ME} (in EEDI formula)	**R**	EEDI as calculated for a ship using EEDI formula and verified by the Administrations or Recognised Organisation on their behalf.
I	EEDI preliminary verification	**S**	Ship speed at 75% main engines' MCR (for more complex propulsion system, it includes elements of main engine, shaft generator, shaft motor, etc.) at clam sea and deep water operation, ……
J	EEDI final verification	**T**	EEDI as calculated from Reference Line and Reduction Rate using the formula given in the relevant regulation.
		U	The baseline curve of EEDI as a function of ship capacity as developed by the IMO for regulatory purposes.
		V	Main engine power at MCR
		W	The ship's maximum deadweight or growth tonnage at scantling draft.
		X	Main engine power at 75% MCR (for more complex propulsion system, it includes elements of shaft generator, shaft motor, etc.)
		Y	The Administration may decide to waive the requirement for attained and required EEDI for a ship by 4 years.
		Z	A verification that takes place at the ship's commissioning sea trials.

(b) Match the correct relevant definitions to the term by completing the "related Definition" column.

Term	Related Definition	Term	Related Definition
A	**R (sample)**	**F**	
B		**G**	
C		**H**	
D		**I**	
E		**J**	

Exercise 2.4 – EEOI calculations

Using the data provided in Table below, calculate the EEOI and complete the cells that are highlighted grey.

Name and type of ship						Calculations		
Voyage or day (i)	Fuel consumption at sea and in port in tonnes			Voyage or time period data		Mass of CO_2 (tonne)	Transport work (tonne-nm)	EEOI (g/(tonne .nm))
	Fuel (MDO)	Fuel (LFO)	Fuel (HFO)	Cargo (tonnes)	Distance (NM)			
1	5	0	20	25,000	300			
2	5	0	20	0	300			
3	10	0	50	25,000	750			
4	3	0	10	15,000	150			
All voyages (for averages)	-	-	-	-	-			

Exercises 2.5 – EEDI calculations using the calculator

Use the "EEDI calculator" and sample "EEDI Technical Files" and calculate the EEDI values for the relevant ships.

Exercise 2.6 – EEDI verification

Use post-it notes, write six (6) main activities that must take place during the EEDI verification. Use diagram below as a guide.

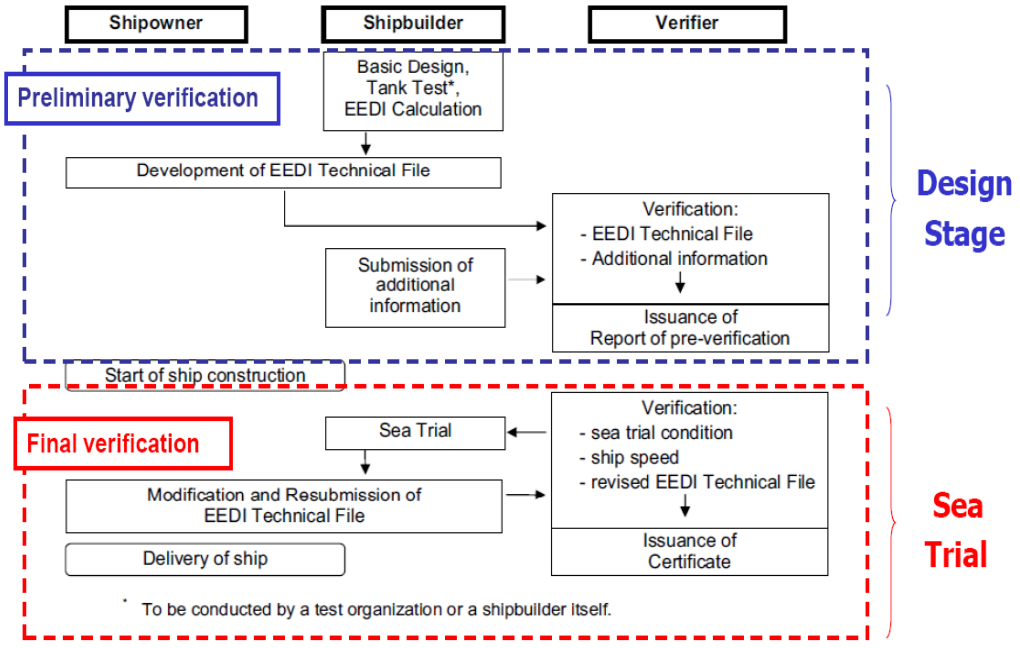


Figure - EEDI Verification process

Module 3 Exercises

Exercise 3.1 – Legal frameworks and their impact on energy efficiency activities

Answer the following questions:

- What is a Bill of lading?
- Explain the difference between a voyage charter and a time charter.
- What is demurrage?
- What is a Demise charter and who is responsible for the maintenance of the ship?
- Explain the impact of various contract of carriage (for example: voyage charter, time charter and demise charter) on activities relating to ship's energy efficiency.

Exercise 3.2 – Slow steaming strategic decision making

A company plans to use slow steaming as the main method for its fuel consumption reduction. Currently, they have 10 containerships (assume all of them to be sister ships at 8500 TEU), each operating at a speed of 25 knots with a propulsion power (main engine) of 54 MW for this speed. They want to slow steam all the ships to 18 knots but carry the same total cargo; thus they need a larger number of ships.

- Discuss how the operation time profile of the ships will change (% of overall voyage time in passage and port)
- Discuss how the fuel consumption profile will be affected (% of fuel consumption in passage and port).
- In terms of overall ship economics, what factors need to be taken into account by the company?
- Approximately, how many extra ships they will require to deploy?
- Approximately, what do you expect the propulsion power to be at 18 knots?

Exercise 3.3 – Slow steaming technical decision making

Discuss the following for the case of extreme slow steaming:

- The likely impact of slow steaming on engines, propeller and hull?
- Why it is important to investigate each item before deciding on level of slow steaming?

Exercise 3.4 – Estimation of the impact of a more Just in Time operation on ship fuel consumption

A ship shows an annual operation profile as follows (baseline condition):

1. Total duration of steaming: 60% (of total time)
2. Total duration of manoeuvring: 3%
3. Total duration at anchorage, port and berth (port-stay): 36%
4. Ship unavailability (e.g. dry-dock): 1%

Using Just in Time principles, the above numbers could be improved to:

1. Total duration of steaming: 70% (of total time)
2. Total duration of manoeuvring: 3%
3. Total duration at anchorage, port and berth (port-stay): 26%
4. Ship unavailability (e.g. dry-dock): 1%

Using these data and assumptions below, calculate the following:

- % reduction in ship speed in passage.
- % reduction in fuel consumption in passage (assume that fuel consumption per nautical mile is proportional to V^2 (speed squared).
- % reduction in CO_2 emissions in passage.
- The annual reduction in days of port stays.
- % reduction in port-area emissions due to this change (assume that this is proportional to reduction in time of port-stay).
- Assume that this ship is using 12,000 MTs (metric tonnes) of fuel for propulsion during passage. The fuel price is $450/MT. How much is the saving per voyage as a result of the move to a more just in time operation?

Exercise 3.5 – Ship trim, normal practices and optimisation

A. A ship has a mean draft of 8 m and a trim of -1.2 m (forward trim is negative trim). Calculate the aft and forward draft for this ship.
B. Answer the following questions:
    a. How the trim of a ship are normally changed in practice?
    b. Are there any port-related activities that could influence the ship trim?
    c. When a ship leaves a port, what is the expected trim of the vessel; based on current normal practices?
    d. Why do ship masters normally prefer even keel or aft trim? In their view, what is the likely impact of the forward trim?
C. Name two main methods/techniques for identifying the optimum trim for a ship?

Exercise 3.6 – Energy efficiency measures

Name one (1) energy efficiency measure for each of the following categories and indicate if your chosen EEM is more effective for tankers or containerships or both:

Category	EEM (Energy Efficiency Measure)	More effective on: tankers or containerships?
Ship resistance reduction		
Ship propulsion efficiency improvement		
Engine efficiency improvement		
Lower energy consumption in auxiliary systems		
Lower energy use in boilers		

Exercise 3.7 – Main Factors that Influence a Ship's Fuel Consumption

Assume you are a ship operator. Select one (1) main factor for reducing your ship's fuel consumption.

- Explain in <u>what way and how</u> this factor impacts your ship's fuel consumption?
- Explain the <u>potential level of saving</u> for the selected factor (e.g. % reduction in your ship's fuel consumption)?
- Discuss the level of <u>cost</u> associated with the implementation.
- Explain the main <u>barrier</u> for the implementation.

Module 4 Exercises

Exercise 4.1 – Estimation of saving: Case for auxiliary engines operation management

Consider the following two cases:

Case 1- Current practice: An analysis of ship-board data on auxiliary engines (diesel generators; DGs) for a tanker shows the following:

- Only 1-DG is operated for 52% of the time.
- For the rest of the time (48%), 2-DGs are operated together.

Case 2 - Best practice: The same analysis shows that with good practice and good load management, the above could be changed to 70% of the time with 1-DG and 30% of the time with 2-DGs.

Using the above data and those in below table, complete the highlighted cells in the table.

Parameter	Unit	Value
Total electric power generation	[kW]	550
Engine SFC at 275 kWe	[g/kWh]	235
Engine SFC at 550 kWe	[g/kWh]	210
Number of hours per year	[hours]	8760
Current Practice		
Period of operation with 1-DG	[%]	52
Period of operation with 2-DG	[%]	48
Total fuel consumption by DGs	[MT/year]	
DGs total run hours	[hours/year]	
Best Practice		
Period of operation with 1-DG	[%]	70
Period of operation with 2-DG	[%]	30
Total fuel consumption by DGs	[MT/year]	
DGs total run hours	[hours/year]	
Savings		
Fuel consumption reduction by change to best practice	[%]	
CO_2 reduction (Assume C_F=3.1144 tonne CO2/tonne fuel)	[%]	
Fuel price	[US$/MT]	600
Fuel cost saving	[US$/year)	
Reduction in engines' run hours	[hours/year]	

Table – Estimation of benefits of auxiliary engines power management

Exercise 4.2 – Ship board energy efficiency measures

You are a Chief Engineer:

a. Name three (3) specific "energy efficiency measures" that directly relate to your area of ship-board responsibilities. Explain your role with regard to each.

b. From the above three, choose the one that in your view require the highest level of coordination between the engine and deck departments. Explain why this cooperation is needed.

Exercise 4.3 – Auxiliary machinery energy efficiency measures

Regarding the load factor and utilisation factor management for auxiliary machinery:

a. Define a machinery's (1) Load Factor and (2) Utilisation Factor
b. Explain for example for a case of a typical ship-board pump:
    a. How the load factor and utilisation factor can be calculated?
    b. Type of data needed for this purpose?
    c. From where you will gather these data?
c. For parallel machinery operations, which of the following is best for energy efficiency:
    a. (1) A high load factor and high utilisation factor.
    b. (2) A low load factor and low utilisation factor.
    c. (3) A high load factor and low utilisation factor and
    d. (4) A low load factor and high utilisation factor.

Choose only one and explain the reason.

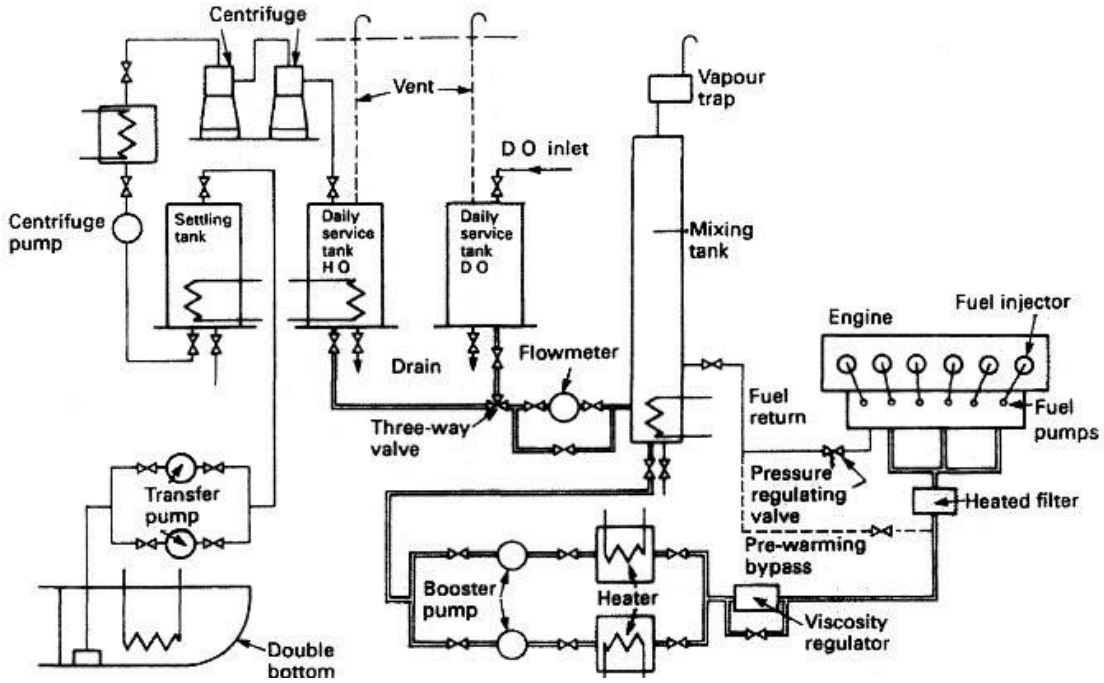
Exercise 4.4 – Ship energy review

Answer the following basic questions in relation to one of your ships:

- How do you know how much fuel your ship is using?
- How the fuel consumption is measured / estimated?
- How can you establish a ship's time operation profile?
- How can you establish the ship fuel consumption profile?
- What is the current energy efficiency performance?
- Explain how the above collectively provide a good picture of current status of the ship's energy profile.

Exercise 4.5 – Fuel management related "energy efficiency measures"

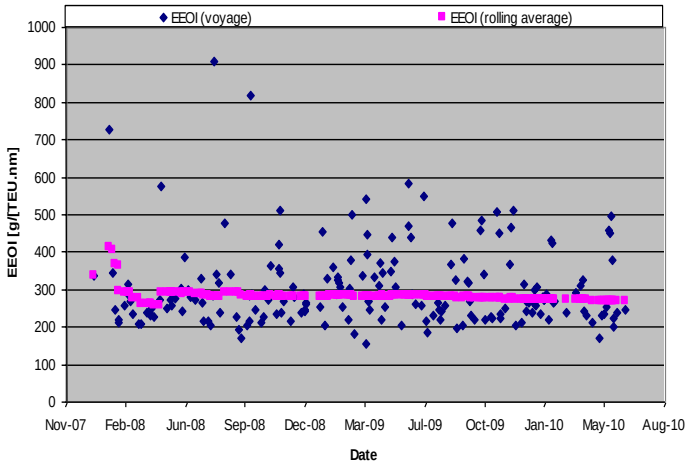
"Fuel management" refers to activities from bunkering of fuel (fuel manifold) to engine exhaust (after combustion). Using post-it notes and with reference to below diagram, identify the important aspects of the chain of fuel storage ➔ treatment ➔ engine and ➔ combustion and how these need to be managed in order to ensure better ship energy efficiency.



Typical fuel oil system for a cargo ship [Source: http://www.machineryspaces.com/fuel-oil-treatment.html]

Exercise 4.6 – EEOI and its variations

The following Figure shows the calculated EEOI for a container ship. Each point on the diagram refers to one voyage. The line on the diagram shows the rolling average for the EEOI.



Variation of voyage-based EEOI for a containership

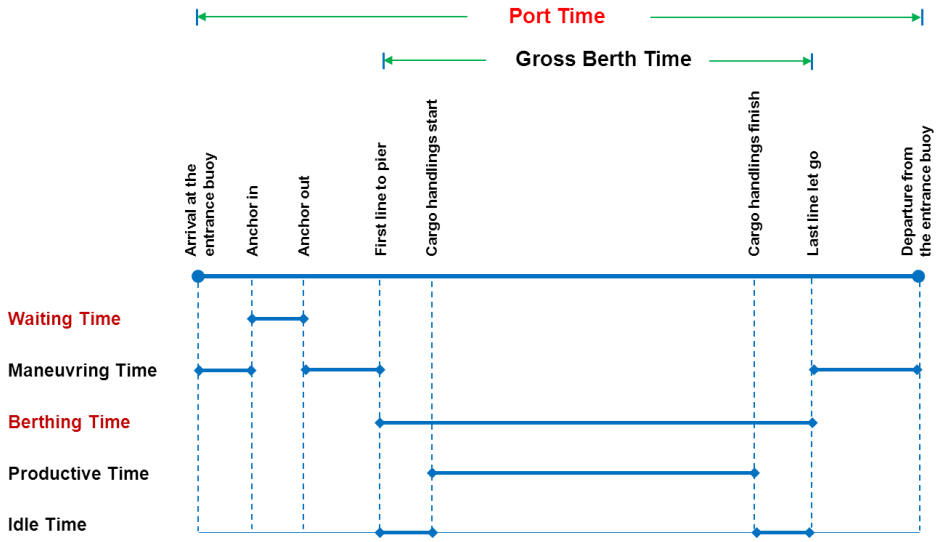
Referring to the above diagram:

- Explain why so much changes happen to the EEOI?
- Name the main parameters that may cause this (at least 4 main parameters).
- Using the rolling average curve above, specify how much is the average EEOI for this vessel.
- Assume that this is a 5000 TEU ship. How EEOI for a 10,000 TEU ship will differ from this ship? The average value will be lower, higher or almost the same? Give the main reason for your answer.

Module 5 Exercises

Exercise 5.1 – Ship's "port time" and its impact

Define the term ship "port time" with reference to the following diagram.



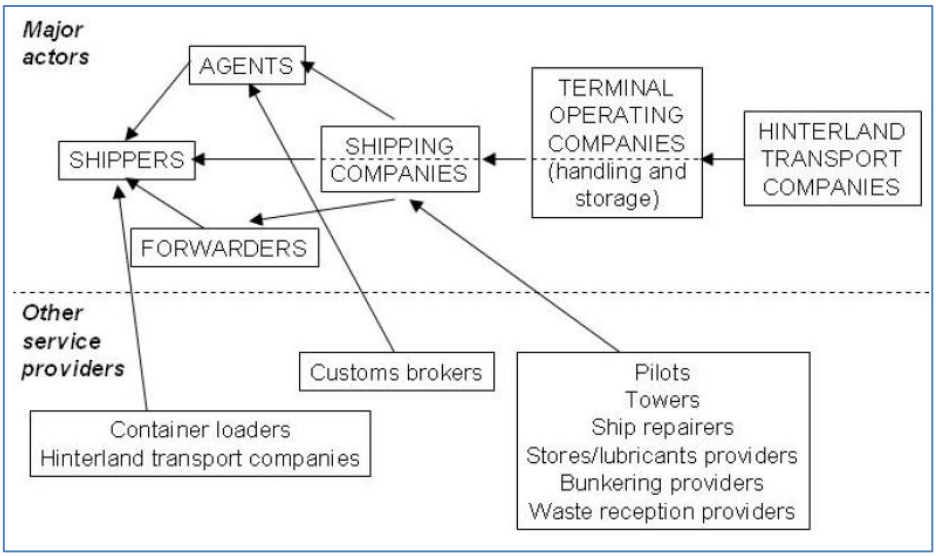
Answer the following questions:

- What is the impact of increased "port time" on a round trip ship's voyage fuel consumption?
- What is the impact of increased "port time" on port area emissions?

For the above cases, assume that total round trip voyage time is fixed.

Exercise 5.2 – Major players in a port

In your group, discuss the following diagram and explain what it tries to show?



Source: Meersman, Van de Voorde and Vanelslander

Name some organisations that play roles in ports with regard to ship operation.

Exercise 5.3 – Port environmental programme or port green initiative

You are responsible to ensure that the port area emissions are reduced with special reference to reducing the use of energy in ports. For this purpose, you can reduce ship emissions while in port or emissions from port facility (buildings, land transport, cranes, etc.).

Concentrate on ship-related emissions, use post-it notes and explain various activities that you will do for improving ship operation / performance in port and reduce ship-related emissions.

Exercise 5.4 – Onshore Power Supply (OPS)

Answer the following questions:

- What is the main aim of using the OPS?
- Do OPS reduce the overall GHG emissions to atmosphere?
- Is use of OPS more energy efficient?
- Is cost of energy to ship higher or lower with OPS?
- Are there any IMO regulations on use of OPS?

Module 6 Exercises

Exercise 6.1 – Energy policy

Answer the following questions

- What is an energy policy?
- What are the main element/topics that need to be included in a shipping company's energy policy? Name at least three (3).
- Who should endorse the company's energy policy

Exercise 6.2 – Data collection and reporting

Answer the following questions

- Explain why data collection and data analysis are so important for energy management?
- With reference to EU MRV, what are the main data requirements for reporting purposes?
- Compare the IMO data collection and reporting system (under development) to the EU MRV and identify their commonalities and their differences.

Exercise 6.3 – Development of a ship energy management plan

Discuss the key steps involved in developing a ship energy management plan. Identify the main guidelines that should be used for this purpose.

Exercise 6.4 – Development of a shipping company energy management system

Discuss the key steps involved in developing a shipping company energy management system. Identify the main guidelines that should be used for this purpose.

Exercise 6.5 – Drivers for shipping energy efficiency

Complete the following for energy management:

	Main driver	**Secondary driver**	**Third driver**
Eco-ship (energy efficient ship design)			
Eco-shipping (energy efficient ship operation)			
Use of ship performance monitoring system			
Ship-board SEEMP			
Company energy management system			

Exercise 6.6 – How will you conduct a ship energy audit / review?

You are tasked to perform an energy audit or review of a tanker. The purpose of energy audit and review is to identify "energy efficiency measures (EEMs)" and their technical feasibility and potential savings.

Assume that no such audit/review has been done before in your company and you are asked to define the process for doing it. Please define the following:

- The process that you will follow (steps that you will take) to conduct this energy audit or review?
- Areas that you will evaluate or assess?
- Examples of types of analysis that you will do?
- Would you conduct any ship surveys? Explain.
- What will be the final outcome of your audit and review?

Present the outcome to the group.

Exercise 6.7 – Develop a framework for a performance monitoring system

You are required to conceptually develop a system for the monitoring of one of the following aspects of a ship:

- Ship total performance (efficiency in relation to transport work)
- Ship hydrodynamic performance (hull / propeller)
- Engines performance
- Voyage performance (speed, distance, just in time, etc.)
- Auxiliary machinery performance (load and utilisation)

In your group, select one of the above topics/aspects. For the topic/aspect chosen, develop a "performance monitoring system" concept via defining the following:

- The system working principle / concept
- The main KPIs (Key Performance Indicators) that you will use/monitor in your system
- Input data to the system
- Analysis method/process
- Output data from the system

Present your system to the group.